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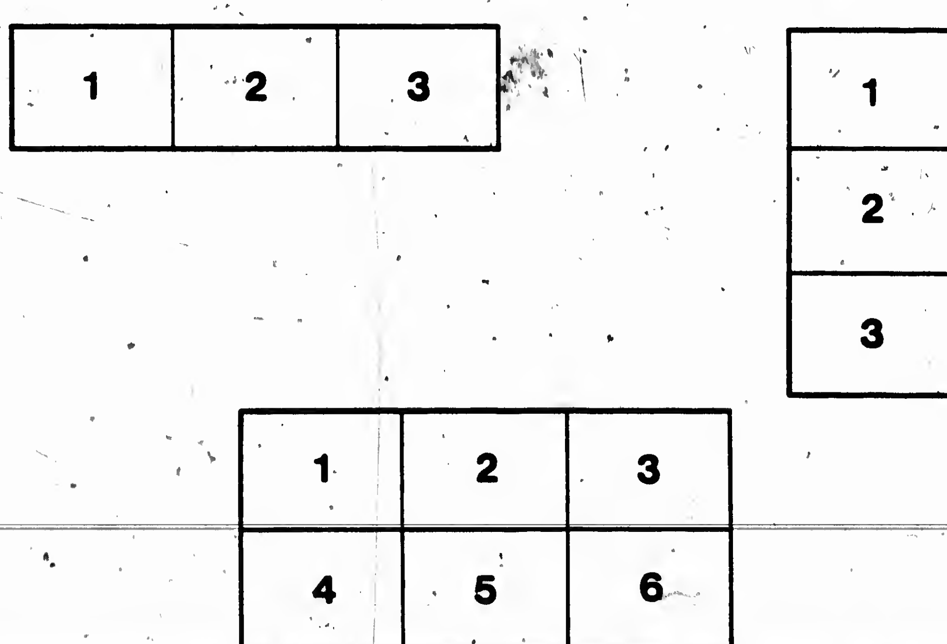

ADDRESS OF

HERBERT WALLIS

PRESIDENT

Canadian Society of Civil Engineers,

AT THE

ANNUAL MEETING,

JANUARY 13TH, 1897.

Canadian Society of Civil Engineers.

PRESIDENT'S ADDRESS.

ADDRESS OF HERBERT WALLIS, PRESIDENT, 1896.

MR. PRESIDENT AND GENTLEMEN,—

Ten years ago the Canadian Society of Civil Engineers entered upon its existence. It was then that the germs which had been for a long time dormant emerged from their condition of embryo, and took material shape, fostered and guided under the parental care of Mr. Thomas C. Keefer, its first President.

If the success of the original conception was at any time problematical, the first six months in the congenial atmosphere of a new life removed the doubt, for during that time the infant Society gave such promise of vitality and endurance, as to claim recognition in the brotherhood of those other societies incorporated by the Dominion Legislature, from which body it received on June 23rd, 1887, a charter, constituting it "a body politic and corporate under the name of the Canadian Society of Civil Engineers."

And following upon this comes the recognition of Civil Engineering as a profession, and the admission of its members by the Legislature of the Province of Manitoba, the first of the provinces to act in this direction, to the enjoyment of privileges of close corporationship, such as are accorded the learned professions of Law and Medicine, a fitting tribute to the importance of Engineering and Mechanical Science and to the work of the Society during the first decade in its history.

And it seems to me appropriate, that you should have elected as President for the ensuing year the gentleman who, as it were, became the father of the Society, when he accepted office at its birth, and when he agreed to occupy the presidential chair during the first period of a possibly struggling infancy. Succeeding generations of engineers will think of Mr. Keefer as a Canadian Telford, and his first address will stand as a reference book in the historical annals of Engineering Science in this country.

It may be truly said, I think, that we are entering upon a year that marks an epoch, perhaps the most important that has yet been chronicled.

And now, gentlemen, it is a duty which I owe to you, as well as it is a privilege and a pleasure to myself, that I should observe the time-honoured custom of addressing you upon some subject of interest to the Society 'ere the close of this meeting, and on my retirement from the office of President, to which office a year ago you conferred upon me the great honour of election.

Presidential addresses have, in the past, not infrequently assumed the character of historical retrospect, and once in a decade at least it seems right they should do so, with the object of reviewing past progress, of registering steps in the march of improvement, of chronicling possibly well known but imperfectly collated facts, and of indelibly marking what otherwise might become mere "footprints on the sands of time."

The last address of this nature was read before the Society in 1889, and it is perhaps with a sense of relief, based upon the knowledge of my own shortcomings, and the belief that others are better able to undertake such a review, that I feel permitted to abstain from inflicting upon you that which under the circumstances might prove uninteresting and wearisome.

There are many subjects commonplace in themselves, whose very commonplaceness makes them interesting. Coal, for example, entering as it does so largely into our domestic economy, is a subject upon which few people are not willing, in some way, to express an opinion, and about this season of the year, when the mercury in our thermometers is ranging in the neighbourhood of zero, it becomes a matter of deep interest to most of us, whether that supply which was so carefully cellared during the summer is going to outlive our necessities, before inexorable laws require that it shall be again replenished.

It has occurred to me, that you might not be unwilling, in lieu of a general retrospect, to hear something about fuel in its various forms, of which coal is one, and especially in its relation to locomotive steam practice in Canada, where, owing to the extremes of atmospheric temperature and to climatic disturbance, the conditions under which it is used are perhaps dissimilar to those existing in most other countries.

Assuming, then, that this should be the case, I shall have to ask you to go with me while I retrace my steps, in reviewing the practice and past operations of the Grand Trunk Railway, that great Canadian artery, with which, as is known to many of you, I have been identified for a quarter of a century, and from which I have collected such data as I propose to bring before you to-day.

I do not claim that my conclusions have been reached as the invariable result of exhaustive experiment, or that my figures are beyond criticism. They are suggested rather as a contribution to practical literature upon a subject which has occupied in the past, and which will unavoidably continue to occupy, the minds of those engaged in solving the great problems arising from the frequent calls for cheaper and more rapid transportation, in connection with which this question of fuel through the energy derivable therefrom stands out as the prominent feature.

The fact that the coal bill alone in the accounts of our great Railways absorbs some 14 per cent. of the total expenditure is sufficient to constitute it, as it literally is, a burning question.

Years ago, when fire-boxes were made of copper and tubes of brass, when their repairs caused no anxiety in the minds of those engaged in their daily work of operating railways, and when their renewals did not constitute an important feature in the general expenditure, the forests of Canada supplied the staple fuel for locomotive consumption.

It is true that trains had to be stopped every forty miles or so, to have the tender loaded with a fresh supply, an operation which occupied ten or fifteen minutes; but these were halcyon days, when time was not so valuable, because competition was not so keen as it is to-day, and no inconvenience apparently resulted from the not infrequent arrival of passenger trains long after their schedule time.

It was only when the possibility of sharing in the distribution of the great produce of the West suggested an assimilation of the gauge of the Grand Trunk with that of the American lines, that it was seen how totally inadequate was cord wood to meet the requirements of a first class railway service.

Even then the substitution of coal had to be very gradually effected, on account of the expense attending the conversion of the locomotives. A wood-burning engine was *hors de combat* after a very short tussle with coal, and the renewals of fire-boxes and tubes were of such a costly nature, as to suggest oftener than not, the substitution of an entirely new engine and the relegation of the old one to the "scrap" heap.

It is not therefore to be wondered at that cord wood outlived for many years the introduction and even the extensive use of coal, particularly upon branch lines, from the neighbourhood of which it could for many subsequent years be obtained cheaply, and also in other districts where competition was the least active, to the extent necessary to wear out those locomotives, which, while being still equal to service, were not worth the expense of conversion.

Fuel wood was purchased by the measure, in cords of 128 cubic feet, and was delivered under various contracts upon the railway "right of way" at the nearest points to the sources of supply. The piles were measured and removed by specially appointed and equipped trains to the wood sheds upon the line of railway, where the process of drying was supposed to be undergone.

For a variety of reasons, however, this process was rarely completed, and, as may be imagined, the fuel differed very widely in its calorific value. The system of acceptance by measurement took no account of the density of fibre or of the amount of moisture it contained, and although hard and seasoned wood commanded a higher price than the soft or greener article, there was no practical means of establishing an accurate or reasonably accurate standard of value as a check upon extravagance on the part of users.

For general statistical purposes, 3,712 lbs. was held to be the average weight of one cord of mixed and seasoned wood, and probably the figure was sufficiently reliable. In the year 1878 careful tests were made to determine the values relatively of the hard and soft woods which were delivered on the line of the Grand Trunk Railway in Eastern Canada. The former comprised chiefly hard maple and birch, and the latter covered those non-deciduous trees of which pine, spruce and hemlock are representative. The weight per cord of seasoned wood was about 4,000 lbs. for hard, and 2,700 lbs. for soft. The result of the tests showed that one cord of the hard wood was fully equal in calorific value to one and a half cords of soft.

So far back as the year 1868, the Grand Trunk Company, with the object of checking the advancing price of cord wood, introduced peat as a competitor. This peat was cut from the bogs at Lapigeonnière and at St. Hubert, in this province, and after being partially cured and otherwise prepared was hauled as in the case of wood to the way station delivery sheds.

The difficulties in its use, anticipated at the outset, were such as applied to cord wood. The crude peat was not uniform in quality, it was liable to imperfect manufacture and to absorb an undue amount of moisture. It was, moreover, very unpopular, owing to the pain its use inflicted upon the eyes of the firemen, and its death knell was rung about the year 1875.

The last year's record, based upon issues of about 80,000 cords of mixed wood at 3,712 lbs. per cord, and of 8,000 tons of peat at 2,000 lbs. per ton, showed a consumption per engine mile of 95 lbs. of the former, and 118½ lbs. of the latter, the actual cost of peat per car mile being about 50 per cent. more than that of wood.

These figures were, however, the result of the daily working of the railway, and the conditions were not perhaps in all respects the same.

In 1876, I made very careful experiments to determine the relative values of the two fuels, upon representations having been made that a superior quality of compressed peat was in the market, which would eclipse anything that had been previously introduced, both as to its calorific value and its price.

The cost of the wood was $3.33 per cord of 4,031 lbs. delivered upon the tender, and that of the peat $1.71½ per ton of 2,240 lbs. similarly delivered, and the evaporative efficiency proved to be 3.09 lbs. and 2.33 lbs. respectively of water per lb. of fuel, while the quantity used per ton of train hauled one mile, excluding the engine and tender, was .263 lb. in the case of wood, and .362 lb. in that of peat, or an excess as against the latter of over 37 per cent.

It was during the autumn of 1873, when, after the gauge of the railway had been changed from Montreal westward, to conform to that of American lines, that the Grand Trunk Company contracted largely for bituminous coal.

During that year upwards of 150 engines, constructed for the purpose, replaced others of the wood-burning type, which were subsequently rebuilt or otherwise disposed of, and the number of coal-burning engines was largely augmented the following year, on the completion of the change which made the Grand Trunk a 4' 8½" or standard gauge railway throughout its entire length.

As a result, the influx of American traffic from the Western States to the seaboard, coupled with the increased capacity and fitness of the new engines, so greatly increased the mileage and added to the weight of the trains, that the superiority of coal and the insufficiency of cord wood as a steam generator could not be ignored, and the absolute retirement of the latter became merely a question of time.

During experiments made in 1876, a locomotive hauling a freight train of 340 tons consumed .263 lb. of hard dry maple, weighing something over 4,000 lbs. per cord, per unit of work (one ton one mile), as against .105 lb. of good Welsh steam coal, and the efficiency of the boiler under similar conditions was 3.09 lbs. and 7.94 lbs. of water evaporated per lb. of fuel respectively.

Similar experiments made at the same time with stationary boilers of locomotive type produced similar results, so that it may be broadly stated that one pound of good steam coal effectually burned will in practice yield an equal result with two and one-half pounds of hard dry maple, or that a ton of coal is equal to a cord and a quarter of seasoned hard wood by measure.

The best of soft woods did not yield by measure more than one half the duty of coal, one ton or 2,000 lbs. by weight producing equal results with two cords.

Meantime the gradual clearing of the country contiguous to the railways was making cord wood difficult to obtain, while competition and improved facilities in transportation were cheapening the price of coal. While therefore the issue of coal during the year 1871 amounted in all but to 200 tons, it had risen in 1875 to 140,000 tons, and in 1895 the quantity used exceeded 700,000 tons, and from the year 1884 cord wood ceased to be used except for lighting fires or to a limited extent for stationary purposes.

In the early history of the use of coal upon the Grand Trunk Railway, the supply was, for the most part, obtained by water delivery, either at Montreal from Cape Breton and Nova Scotia, with occasional cargoes from Great Britain, or at Toronto, Belleville or Brockville, by way of the lakes from the coal fields of Ohio and Pennsylvania.

Thus a large stock had to be provided during the season of navigation to meet winter requirements, which, by exposure to the atmosphere (for the quantity was too large to admit of it being piled under cover), lost much of its calorific value by decomposition and the gradual volatilization of the hydrocarbons. This loss was accentuated, in coals which contained sulphur, in a more than ordinary degree, to the extent that active combustion not infrequently followed upon or resulted from the heat generated on account of its presence.

The loss by breakage in loading and unloading the vessels, as well as the loss of interest on invested capital, furnished additional reasons for inducing the opening of all rail routes, and for making recent contracts on the basis of continuous daily delivery.

Coal from some seams, owing to a soft and friable nature, is specially liable to damage in the process of mining and subsequent handling, and quantities varying from 75 to 25 per cent., according to the nature of the coal, pass through the screens, in the form of dust and slack, which, if used in the fire-boxes, would escape through the tubes in a condition wholly or partially unconsumed, thus helping to swell the volume of smoke, which imperfect combustion the result of forced fires too often produces.

It has often become a question as to whether it is not desirable to forego the expense of screening, and to be satisfied with what is known as the "run of mines" supply.

The result of experiments made in 1887 with coal from three widely separated mines indicated a higher evaporative efficiency in favour of screened coal by as much as 7½ per cent. In these trials one car load from each mine was used as delivered under a "run of mine" contract, as against other cars from which the coal was handpicked.

The comparative freedom from smoke and dust seems to point to the desirability of screened coal for passenger train service, and in countries like Canada, whose importations are large, and where the import duty is alike for screened and unscreened coal, it is a question if the balance of advantage is not in favour of the former.

Pennsylvania anthracite, or what is usually known as hard coal, has not found favour in Canada as a locomotive coal, owing to its relatively higher first cost.

For passenger train service, it cannot be excelled, on account of its freedom from smoke and dirt, but it requires from 12 to 15 per cent. more by weight to equal the duty obtained from bituminous coal, and the greater wear and tear consequent upon its use shortens fire-box life from one to two fifths.

A very careful record made under the supervision of Mr. T. N. Ely, chief of motive power of the Pennsylvania Railroad Company, showed that during one month, the amount by weight of anthracite coal required to work the local trains leaving Broad street station, Philadelphia, exceeded by 11 per cent. that of bituminous coal required to perform the same work.

On the Reading Railroad, where the use of the Wooten boilers permits of a very large fire grate area, the evaporative efficiency of soft coal was superior by 15 per cent.

Patent fuel, a combination of coal dust and tar manufactured under pressure into "briquettes," while giving good evaporative results, has not, owing to the cost of production, been equal to successful competition with coal.

Petroleum by-products have been tried, and are successfully used in Russia. In Canada, the uncertainty as to cost, owing to limited area and extent of production, and the unavoidable risk which would attend operations on a scale of sufficient magnitude, constitute objections which are not likely to be overcome, so long as coal can be obtained at or about present prices.

On the Great Eastern Railway of England satisfactory results are reported from the residual product of the illuminating gas used in passenger coaches. On that railway the oil and coal are used together, and the ultimate cost of operating is about the same as for coal alone; but a use is thus found for a refuse commodity which otherwise would be difficult to dispose of.

To accomplish a given amount of work, petroleum occupies about one-half the space of coal, and this fact is no doubt a point towards a favourable consideration of its merit.

I will now call your attention to some of the influences which affect the consumption of fuel in locomotives.

Apart from the loss sustained through interruptions and obstructions by snow, there is a well defined condition of inverse ratio due to heat radiation from the boiler and cylinders on the one hand, and to the temperature of the feed water on the other, existing as between atmospheric temperature and fuel consumption.

Some interesting information as to relative summer and winter operations extending over a number of years will be found in the following figures :—

YEAR.	JANUARY.				FEBRUARY.				JULY.		AUGUST.	
	Coal used per car per mile, lbs.	Temperature of atmosphere, Montreal.	Snow fall, Montreal, inches.	Snow plow miles run per mile of railway.	Coal used per car per mile, lbs.	Temperature of atmosphere, Montreal.	Snow fall, Montreal, inches.	Snow plow miles per mile of railway.	Coal used per car per mile, lbs.	Temperature of atmosphere, Montreal.	Coal used per car per mile, lbs.	Temperature of atmosphere, Montreal.
1882..	4.02	13	23	.69	3.74	19	23	.99	2.83	68	2.86	68
1883..	4.46	6	20	4.71	5.80	12	17	10.78	3.00	67	3.08	66
1884..	5.23	6	44	6.68	4.56	18	29	1.97	2.95	68	2.95	70
1885..	4.15	13	22	1.03	4.95	4	44	5.87	2.96	71	2.91	64
1886..	4.02	11	17	.82	4.06	11	10	2.38	2.92	70	2.96	68
1887..	4.63	5	50	10.17	4.50	12	34	6.98	2.99	75	3.12	66
1888..	4.76	2	34	5.63	4.41	13	30	2.15	3.15	70	3.32	65
1889..	4.14	9	41	.60	4.87	9	32	7.48	3.21	69	3.26	65

These figures are based upon the total car mileage of the Grand Trunk Railway. It is quite true that a possible variation in the rate of train speed or in the weight of the cars or their contents would interfere with a too close comparison as between one year and another. They are nevertheless quite reliable as illustrating my remarks. The figures show that over a series of eight consecutive years, the average weight of coal required to carry the freight traffic of the Grand Trunk Railway was 50 per cent. more per car per mile during the months of January and February, than during those of July and August.

They also show that while January has been the colder month during the time referred to, the rate of coal consumption has been relatively higher in February, owing no doubt to greater interference by snow during that month. If exception should be taken to the use of Montreal thermometric records, I will say that the traffic of the Grand Trunk Railway is chiefly derived from the West, and that the prevailing winds from that quarter seem to regulate the atmospheric temperature in something like an equal ratio throughout the section of country to which the statistics apply.

This will be seen from the records in degrees Far., also given, for the months of January and February, 1888 and 1889, at the five terminal points:

YEAR.	Detroit.		Buffalo.		Toronto.		Montreal.		Portland.	
	Jan.	Feb.	Jan.	Feb.	Jan.	Feb.	Jan.	Feb.	Jan.	Feb.
1888........	15	21	17	21	15	22	2	13	11	19
1889........	27	16	29	18	28	18	19	9	27	17

The following figures give the coal consumption per car per mile for each month during 1895:—

1895.	Temperature of air, Far.	Cars per train.		Speed of trains in miles per hour.		Coal consumed in lbs. per car per mile.	
		Pass'r.	Freight.	Pass'r.	Freight.	Pass'r.	Freight.
Jan.....	14.9	4.7	17.5	21.1	11.9	13.19	4.95
Feb.....	14.2	4.5	17.4	19.3	10.5	13.85	5.08
March. .	22.1	4.6	18.6	21.5	12.2	12.25	4.41
April. ..	41.2	4.8	19.1	22.0	12.8	11.18	3.84
May....	58.3	4.8	19.3	22.2	12.9	10 51	3.53
June. ..	69.5	4.9	18.7	21.9	12.9	10.31	3.40
July. ..	67.2	5.2	18.2	21.7	12.8	10.20	3.47
August.	65.8	5.3	18.0	21.6	12.7	10.14	3.53
Sept....	60.3	5.4	18.8	21.8	12.8	10.16	3 57
October.	41.2	4.9	19.0	22.7	12.5	11.07	3.91
Nov.. ..	34.3	4.8	19.5	22.9	12.2	11.62	4.13
Dec.....	22.5	4.9	19.0	22.5	11.8	12.22	4.37

I have included the results of the passenger as well as of the freight train service, though the latter furnish the better guide, owing to the fact that freight trains are, as a rule, worked more closely to the capacity of the engines. The average rate of speed is also recorded, and the number of cars of which the trains were made up, so that these influences upon the rate of fuel consumption may be duly appreciated.

Unfortunately the weight of the trains is not obtainable, though it is likely the variation as between one month and another for a year would not be important.

The advantages accruing to railway companies, whose lines are removed from the rigour of our Northern latitudes, is made by these figures sufficiently apparent.

The influence of gradients and curvature may here be illustrated by reference to trials made some years ago on the main line of the Grand Trunk Railway between Sarnia, a town situated on the river St Clair and Portland, Maine, the distance being 798 miles. This mileage was divided into nine locomotive divisions, of which the shortest was 58 and the longest 125 miles in length.

A locomotive having cylinders 17 inches diameter and 24 inches long, with four coupled driving wheels of 62 inches diameter over the tires, made the run over the entire distance, completing the work of one division each day, with a freight train of a weight corresponding to its capacity. The fuel was of the same quality, and was accurately weighed, and the trials took place at a time of year and time of day when the variation of atmospheric conditions was inconsiderable.

The intention was to compare the cost of working upon the various divisions, and no effort was spared to ensure accuracy in the result.

The following table gives the particulars:—

DIVISION WEST TO EAST.	Miles apart.	Difference in altitude of terminals, feet.	Lift between terminals, feet.		Cars per train.		Tons per train.		Coal in lbs. per mile.				
									Per Train.		Per Ton.		
			East.	West.	East.	West.	East.	West.	East.	West.	East.	West.	Average.
Sarnia & Stratford ...	80	57	615	...	21	35	494	346	57.75	34.39	.1169	.0993	.1081
Stratford & Toronto ..	88	937	...	994	21	32	494	346	36.20	59.16	.0733	.1708	.1221
Toronto & Belleville..	113	59	305	275	19	35	448	315	48.07	42.57	.1076	.1352	.1214
Belleville & Brockville.	95	5	100	110	21	35	489	345	44.20	43.52	.0904	.1262	.1083
Brockville & Montreal.	125	230	...	300	27	45	617	345	45.24	46.76	.0751	.1050	.0900
Montreal & Richmond.	76½	345	565	225	23	35	541	344	56.62	36.86	.1106	.1160	.1133
Richm'd & Island Pond	71	796	989	...	19	35	446	344	63.77	28.25	.1431	.0822	.1126
Island Pond & Gorham	58	389	...	389	24	35	563	344	41.56	50.22	.0738	.1461	.1099
Gorham & Portland...	91½	787	...	787	24	35	563	344	34.70	49.45	.0616	.1526	.1071

The cars were loaded going eastward and empty westward, in consonance with the general direction of traffic. It will be noticed that the consumption of fuel per ton per mile is fairly proportional to the lift in feet. In cases where this rule does not obtain, excessive curvature, the assistance of a pilot engine, or a longer run between stations, reducing the percentage of coal used in firing up, may be said to account for the difference.

The variation in the rate of consumption is from 1 to 2.3 in connection with eastbound, and 1 to 1·85 with westbound trains.

In August, 1882, arrangements were made under which the Grand Trunk and Great Western Railways were cemented into one system under Grand Trunk management.

Each Company owned a line from the West to the Niagara frontier, and also to Toronto.

Owing to representations made by myself, it was decided to make use of the Great Western line, which with its lower gradients runs nearer to the level of the lakes, for eastbound "through" freight traffic, and to convey the westbound business, consisting largely of empty or return cars, by way of the main line of the Grand Trunk, which rises, in the neighbourhood of Stratford, to an elevation of 1000 feet.

Thus the partial effect of a double line of railway was secured, and the easiest gradients were made use of for the heaviest trains.

The new, or what has been since called, "circular" system went into operation September, 1883, and the first three months gave the following results :—

	October 1st to December 31st.			
	Western Division.		Central Division.	
	1883.	1882.	1883.	1882.
Coal tons	18,365	20,669	33,878	32,484
Train miles	505,821	550,170	794,608	827,037
Car "	10,432,390	10,315,884	19,466,668	19,747,683
Cars per train	20.6	18.7	24.5	23.9
Coal, lbs., per train mile	72.61	75.14	85.27	78.56
" " " car "	3.52	4.01	3.48	3.29

The two divisions, viz., the Western and Central, met at Toronto, and the figures show how the former working under the "circular" system compared with itself when under the old system, and with the Central division upon which the system remained the same.

It will be seen that while the coal requirements per car per mile increased on the Central division, due to various causes applicable to both, by six per cent., they decreased on the Western division by twelve per cent., thus effecting a saving of over 2,500 tons, and a very much larger saving, if it is, as it reasonably may be, assumed that the then prevailing conditions would have warranted the rate of increase which obtained upon the Central division.

It is an interesting fact that while the empty engine mileage westward advanced by 37 per cent. on the Central, the advance was 18 per cent. on the Western division, showing the advantage of a better balancing of traffic under the "circular" system.

The desirability of low grade railways is of course understood, but a greater regard for the cost of operation, especially in the matter of fuel, would often prevent the construction of lines of railway which are destined from their inception to be unprofitable ventures.

It may be safely asserted that the great increase which has taken place within comparatively recent years, in the haulage power of locomotives, has reduced the rate of coal consumption per unit of work (one ton one mile).

The train mile, that most unreliable standard of work measurement, has in the past unquestionably been the means of encouraging the use of small engines, and thus of interfering with economical operation.

It may, however, be doubted whether improved service in the form of more roomy coaches, frequent trains and more rapid transport induced by keener competition has not more than absorbed the savings which might otherwise have been effected.

The old 40 feet coach has expanded into the 55 feet car of to-day, with its wash and smoking rooms and other conveniences not thought of 25 years ago, so that its weight has been added to, without material or proportionate increase of carrying capacity.

The calls upon the locomotive boiler for steam to warm the cars, to apply the brakes, to ring the bell and to signal the train could only be effectually responded to by a more frequent resort to the coal bin, and these calls must of necessity be intensified with an increase in the rate of train speed.

To reduce the drain upon the boiler, the compound engine has without doubt been effective, and the use of steam pressure as high as 200 lbs. per square inch, a natural outcome of the compound principle for single expansion engines, has been productive of economy. Additional attempts have been made, with more or less success, to utilise exhaust steam to raise the temperature of the feed water, more attention has been paid to the boiler clothing and to the graduation of the value "cut off," and slower and more perfect combustion has resulted from the abandonment of double exhaust nozzles and from the use of the extended smoke-box and improved arrangement of the netting and diaphragm plates forming that necessary evil, the spark arrester.

Material benefit has been derived from the duplication of main lines in crowded thoroughfares from the correction of grades and from the greater stability and more perfect alignment of the permanent way.

More care has also been exercised in design, and specially in regard to the better relative proportions as between tractive force and adhesion, the engines of years ago being very deficient in weight for the capacity of their cylinders.

An interesting comparison may be made as between the years 1875 and 1895, if applied to the Central division of the Grand Trunk Railway for the last six months of each year.

During both periods the fuel consisted of soft coal, but during 1875 the locomotives were practically all of one type, having cylinders 17″ x 24″ and working with from 135 to 140 lbs. boiler pressure. In 1895 the passenger engines had 18″ x 24″ cylinders, the steam pressure was from 160 to 180 lbs. per square inch, and the freight engines working at the same steam pressure had 18″ x 26″ cylinders. The Central division covered 333 miles of railway between Montreal and Toronto, and the train mileage over it exceeded two millions during the six months.

The figures are here given :—

SIX MONTHS ENDED	Passenger trains.			Freight and mixed trains.				
	cars per train.	Lbs. of coal per		cars per train.	Lbs. of coal per			Tonnage per train excluding engine and tender.
		car mile.	train mile.		ton mile.	car mile.	train mile.	
Dec. 31st, 1875.	7.4	6.39	47.57	21.9	.18	2.83	61.87	340
do 1895	5.9	10.57	62.13	25.1	.16	3.37	84.62	517

Turning to the working time tables for this division, I find the schedule rate of speed in the earlier period to have averaged 24 miles per hour for passenger trains, while the average during the latter period was 30 miles per hour, being an advance of 25 per cent. The passenger trains though composed of fewer cars did not, though this cannot be actually demonstrated, show a material decrease of weight. As a matter of fact, the larger engines were needed to meet the requirements of faster service, and to secure the comforts and safe-guards, which during the intervening period railway companies were called upon to provide.

As regards freight trains, the average weight has been estimated, on the basis of 10 tons in 1875 and 12 tons in 1895 per empty car, which together with the actual weight of the contents, and exclusive of the engine and tender, make up the train tonnage, which, it will be noted, has increased in the later period by 50 per cent., a circumstance to which must be attributed the improvement recorded in the rate of fuel consumption per ton per mile.

Freight trains were not scheduled in the time tables during the years under consideration, and the average rate of speed cannot therefore be drawn from that source; but dating from the year 1886, very accurate records of averages were kept, and these show that the rate of speed in 1895 exceeded that of 1886 by eleven per cent.

It is a fact, however, that the calls upon freight engines for what may be called extra work have not been so numerous or exacting as upon those engaged in working passenger trains, and it is also true that the former have benefited to a greater extent by the reduction in delays or train detentions, consequent upon the establishment upon this Central division of a practically double track railway.

"The greater the tonnage per train the greater the gain" ought to be a good maxim to adopt in dealing with freight traffic, especially with the traffic of those railways which are called in the United States and Canada the "Trunk lines," and of which the Grand Trunk is an example.

Such a maxim suggests easy gradients and curves, allied with a road-bed and structures of sufficient stability for rolling stock of the maximum carrying capacity, and the observance of such a maxim would yield a profitable return out of all proportion to the necessary increase in dead weight of train, while a reduction would follow in the rate of those operating expenses of which the cost of rolling stock maintenance partially and wages almost wholly may be considered as proportional to the number of trains rather than to the tonnage per train.

The consideration of my subject from this standpoint suggests a reference to the compound principle as applied to locomotive engines.

In the autumn of 1895 the Grand Trunk Company completed, in their work-shops at Montreal, the construction of two locomotives, of which the first, being No. 567, had a pair of cylinders 18 inches diameter, with a piston stroke of 26 inches, its weight in working order being 100,212 lbs. and which was worked single expansion at a boiler pressure of 190 lbs. per square inch; and the other No. 326 being of the compound type, having a high pressure cylinder of 19 inches and a low pressure of 29 inches diameter, with a piston stroke also of 26 inches, and carrying a steam pressure of 190 lbs. per square inch. This engine weighed 118,412 lbs. Both engines had three pairs of coupled driving wheels of 62 inches diameter outside the tires, and virtually were of the same design.

These engines were placed on that section of the Central division which extends from Montreal to Brockville, 126 miles in length, and for a number of trips the results were accurately kept in order to determine the relative fuel consumption.

A distinction has been made in the table of figures which is submitted, as between the west and east bound trips, because the trains composing the former consisted of mixed empty and loaded cars, whereas the east-bound cars were all loaded, also because the gradients are in favour of east-bound trains.

The coal used on the trips from Brockville was from the Punxsutawny mines, Pennsylvania, and at Montreal it was supplied by the Dominion Coal Company from their Gowrie mine, Cape Breton.

Great care was taken to prevent loss of water or steam at the safety valves, from the injectors, or by priming, so as to ensure as far as was possible accurate comparative results.

The trials were made during the months of September and October

	Single Expansion.			Compound.	
	394	567		326	
	East.	East.	West.	East.	West.
Train miles........	2,000	630	504	756	630
Car "	54,000	33,516	21,042	38,556	26,149
Ton "	1,186,289	875,649	418,792	1,007,914	556,787
Cars per train.....	27	52.2	41.75	51	41.5
Tons " " ex engine and tender..	593	1374.7	830.9	1333.2	883.8
Weight of loaded car, tons........	22	25.8	19.9	26.1	21.5
Coal used, lbs......	107,555	71,035	57,280	53,220	48,085
Coal used per train mile, lbs........	53.78	112.8	113.6	70.4	76.3

	Single Expansion.			Compound.	
	394	567		326	
	East.	East.	West.	East.	West.
Coal used per car mile, lbs.	2.00	2.12	2.72	1.38	1.84
Coal used per ton mile, lbs.	.091	.081	.137	.052	.086
Coal used per sq. foot of grate per train mile.	3.36	6.18	6.22	3.88	4.19
Water evaporated, lbs.	792,253	394,842	301,292	353,976	309,556
Water evaporated per train mile, lbs.	396	627	598	468	491
Water evaporated per ton mile, lbs.	.668	.451	.719	.351	.556
Water evaporated per lb. of coal, lbs.	7.37	5.56	5.26	6.65	6.44
Water evaporated per lb. of coal from and at 212°	8.81	6.78	6.31	7.98	7.73
Temperature of air Far.	69.2	53.6	53.4	66.5	72.6
Temperature of feed water	62.73	48.6	48.8	69.1	68.6
Boiler pressure, lbs. per sq. inch	122.6	174	171	175	177
Rate of speed, miles per hour	19.6	19.2	19.4	21.	21.3
Engine in steam per 100 miles, hours, minutes	10.5	8.0	7.4	7.3	7.3
Stoppages per 100 miles	12.9	7.9	8.5	7.6	7.8
Ashes and clinker.	12,580	3600	3275	3520	3235
Per cent. of coal	11.7	5.07	5.72	6.61	6.72
Fire grate surface, sq. feet	16	18.25	18.25	18.25	18.25
Heating surface, sq. feet	1099.6	1122	1122	1122	1122
Weight of engine in working order, lbs.	70,000	100,212	100,212	118,412	118,412

For additional comparison I have added another column containing particulars of a trial made in the autumn of 1882 with No. 394, one of the old type of freight engines having cylinders 17″ x 24″, and two pairs of coupled drawing wheels also 62 inches diameter over the tires. The initial boiler pressure in this engine was 140 lbs. per square inch, and the train mileage was wholly in the easterly direction, viz., from Brockville to Montreal.

Comparing the results of the single expansion types, it will be seen that the larger engine consumed less fuel per ton of train per mile by 11 per cent., notwithstanding the inferior evaporative efficiency of its boiler, due to the disproportionate area of fire grate (unavoidable in this type of engine), and in spite of the loss of power due to the extreme length of train.

Extending the comparison to the compound engine in the same direction of travel, it will be seen that with a somewhat similar train length and tonnage, the gain, expressed as in the previous case, per unit of work over the larger of the two single expansion engines was 35¾ per cent., and over the smaller, of 42¾ per cent., and in respect of westbound trains, the comparison as between the single and compound engines of the same capacity closely approximates to these figures, the difference in favour of the latter being 37½ per cent.

A very interesting and instructive feature in these figures is that which shows that a locomotive boiler is not, as ordinarily arranged, capable of economically supplying sufficient steam, under the extreme conditions which obtain on this continent, or perhaps I should say in this country and in the United States.

Train tonnage has increased without, as a rule, a corresponding increase of boiler capacity, and fire grate area and heating surface are generally altogether inadequate to economically fulfill the conditions now imposed upon them.

Especially is this the case with the fire grate area, as will be seen by reference to the figures of coal consumption per square foot, per train mile, and those of water evaporated from and at 212° per lb. of coal consumed.

It will be seen that the firing of engine 567 was forced to an extent that reduced the evaporative efficiency of its boiler, and although, owing to its heavier train, the engine was able to show a lower rate of fuel consumption than No. 394, the rate was greatly in excess of No. 326, which, on account of the second expansion in the larger cylinder, required less fuel, and was thus able with the same grate area to shew a higher comparative efficiency.

In running engines 567 and 326 without trains over the same division, it was found that the boiler of the former evaporated from and at 212 deg., 10.09, and of the latter 9.24 lbs. of water per ton of coal.

The following figures show the effect of train tonnage upon the consumption of coal per ton per mile, and the effect of the quantity of coal burned per square foot of fire grate, per hour and per mile upon the evaporate efficiency of the boiler.

In these figures, the engines and tenders are included in the total train tonnage.

Engine no.	Direction of train.	Size of cylinders.	Tonnage of train.	Coal (lbs.) consumed per ton mile.	Coal (lbs.) consumed per sq. foot of grate area per hour.	Coal (lbs.) consumed per sq. foot of grate area per train mile.	lbs. water evaporated per lb. coal from and at 212°.	Remarks.
567	East.	18 x 26	90	.231	27.7	1.14	10.09	engine only.
326	"	19 / 29 } x 26	100	.240	36.8	1.31	9.24	do.
394	"	17 x 24	666	.081	65.8	3.36	8.81	
326	"	19 / 29 } x 26	1433	.049	81.5	3.88	7.98	
326	West.	19 / 29 } x 26	984	.077	89.3	4.19	7.73	
567	East.	18 x 26	1465	.076	118.6	6.18	6.78	
567	West.	18 x 26	920	.125	120.7	6.22	6.31	

In boilers of more recent construction for burning soft coal, the much desired increase of grate area has been obtained by raising the level above that of the frames, thus securing greater width and allowing of an extension over the rear drawing axle. Such an arrangement adds materially to the weight of the engine, but the grate area can be doubled.

It is fairly well established, that a well designed locomotive on the compound principle will effect a saving in steam, under equal conditions of 20 per cent., and thus it would seem that further economy in coal consumption lies for the present in that, rather than in the direction of abnormal increase in the weight of engines which now sufficiently tax the endurance of existing roadbed and structures.

And in closing, gentlemen, it remains for me to thank you, and I take this opportunity of thanking you again for the honour conferred upon me in my election to the presidental chair, and for your confidence during my year of office.

That the year 1896 has not been without its peculiar anxieties and responsibilities, you will all probably understand, but the ready and cordial co-operation of the Council has made these comparatively light. To these gentlemen and to the office-bearers I tender my best thanks. I need scarcely say that though my responsibilities will be lighter, my interest in the Society's welfare will not abate, and I venture to hope and to believe that this new year upon which we have entered will be a happy and prosperous one for the Society as a body, as I wish it may be for each of you individually.